Smart Mobility in Smart City: A Critical Review of the Emergence of the Concept. Focus on Saudi Arabia

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Abstract Today, half of the world's population lives in urban areas where information and communication technology (ICT) are natural catalysts for innovations. Progressing urbanization requires improved urban planning and management to make urban spaces more inclusive, safe, resilient, and sustainable, as outlined in SDG11. The concept of smart city offers a way of reconciling the diversity of challenges that the urban space is exposed to today, whereby ICT is considered a tool in this respect. Arguably, smart cities create the opportunity to integrate advances in ICT in the fabric of the city, thus creatively and innovatively provide improved quality of life. The domains of mobility, economy, environment, etc. are just a few examples. The objective of this paper is to focus on the domain of mobility in the smart city and to examine it from a historical perspective, i.e. starting by introducing the concept of smart mobility and its role in creating smart cities, identifying the related technologies and challenges, exploring the different types of smart mobility, and outlining international initiatives. The application of smart mobility in the Saudi Arabia context is highlighted.

Keywords Smart cities · Smart mobility · Smart communities · Smart cities dimensions · Social interaction · Quality of life · SDG 11

1 Introduction

Rapid urbanization and high demands on the quality of life created a need for enhancements in all areas of infrastructure within cities to make urban areas more inclusive, safe, resilient, and sustainable. Therefore, the idea of smart cities has emerged to cope with resources and limited spaces worldwide by highly advanced technology. Scholars specified these dimensions into six main categories: smart economy, smart

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people, smart governance, smart environment, smart living, and smart mobility [1]. While extant literature exists that elaborates on each of these components of the smart city, a little less has been written about these domains from a historical perspective, i.e. in a manner that would seek to trace the emergence and the evolution of the concept. By focusing on smart mobility, this paper seeks to do just that. The argument in this paper is structured as follows. First, the concept of smart mobility is introduced.

Smart mobility has the potential to move from a critical problem to a possible source of improvement and transformation for modern cities. Urban mobility planning in the contemporary world must begin considering the need to promote safer, integrated, and, above all, sustainable means of transport [2]. The research utilizes a qualitative investigative methodology to comprehensively investigate the research topic and provide a complementary and supplementary exploration by collecting, reviewing, and analyzing the literature on smart mobility's characteristics, concepts, models, and challenges.
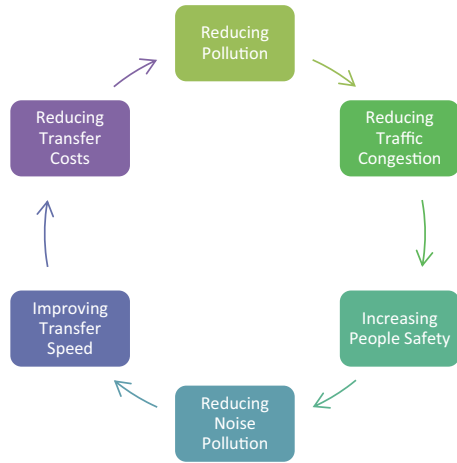
2   Smart Mobility

One of the most difficult topics to face in urban areas is mobility, as it involves both economic and environmental aspects that need higher technologies and virtuous people behaviors [2]. Smart mobility plays a crucial role in the ecosystems of complex smart cities as it is an important factor to allow cities to transform into intelligent cities [3]. Smart mobility can be identified as a general term to describe technologies related to transportation in urban areas. It represents a new transportation approach, including creating a sustainable system [4]. Benevolo et al. [5] has identified many advantages of smart mobility and categorized the main objectives into six points illustrated below (see Fig. 1). Smart mobility impacts the transportation systems in cities, leading to an impact on the environment. Consequently, it has become an increasingly present theme in sustainability agendas. The concept of smart mobility has evolved mainly from merging the digital revolution with the transport industry. Thus, new technologies have increased transport network efficiency [6].

3   Smart Mobility Technologies

Smart mobility is largely permeated by ICT, used in both backward and forward applications to support the optimization of traffic fluxes and collect citizens' opinions about livability in cities or the quality of local public transport services [5]. Within the latter domain, researchers found evidence that traffic is important to allow flexible movement within cities, but traffic time negatively impacts individual well-being. Prior studies also show a strong positive relationship between traffic time and city life satisfaction. Traffic has a measurable negative effect on the life quality of citizens,

Fig. 1 Smart Mobility's
main objectives [5],
Developed by the author

and commute time plays a significant role in cities and entire countries. Therefore, the optimization and improvement of transport, mobility, and logistics in urban areas is a crucial goal in realizing the potential of smart cities. The authors stress that mobility is critical for regions' and cities' intellectual development and growth. The huge problem of traffic congestion requires the development of more sophisticated transportation concepts. Apart from these impacts on citizens' quality of life, traffic leads to air pollution that negatively impacts respiratory health. As one possible solution, several nations are deploying electric vehicles and charging stations to build green transportation networks [7, 8].

The technology of information and communication (ICTs) and digital technologies have improved the smart city concept. Government agencies have begun to invest in ICT systems, such as applications for individual use, cameras in monitoring systems, and sensors, aiming at positive changes in citizens' daily lives [5]. In this context, the use of ICTs in urban mobility has played a prominent role in promoting more sustainable and efficient transport, as in the case of interconnected services and technologies that allow car-sharing, bike-sharing, ride-sharing, buses, and trains [9]. In combination with the need for more flexible mobility and low CO_2 emissions, these technologies have resulted in the dissemination of these new initiatives in the field of mobility, thus making such mobility more intelligent [6].

4 Smart Mobility History

The history of urban transport knew many changes caused by diverse people's travel choices that gave birth to three types of cities. Walking Cities was the first idea proposed by British architect Ron Herron in 1964. Ron characterized the walkable city as tight streets with a large population density, and different mixed land uses.

After that the Automobile City emerged after the second world war. A city type built upon transport modes had an important changeover due to the technological development of transport types to move quickly to any destination. Then in the late twentieth century, Transit Cities emerged to develop public transport to integrate trains' railways, and trams' routes to spread the cities while reducing the density of the population [10, 11].

Furthermore, the evolution of metropolitan areas worldwide resulted in a transformation of lifestyles and mobility practices; this made individuals move freely by using different transportation modes increasingly for diversified reasons. A new term called "Urban Mobility" emerged to solve traffic problems such as congestion and delays to account for the complexity of mobility practices and the strong link between transformations and movements. Then Smart mobility came to attention in the early 1980s by having electric cars solve air pollution problems in larger cities [12].

Moreover, in 1990, California introduced its first zero-emission regulations by creating new projects for improving electric vehicles. Zero-emission vehicles became a new term applied. However, in this context, the focus should be on the sustainable development conversation. Since the late eighties of the last century, a new focus began on developing alternative resources of energy and technologies in transportation sector. This focus has become a major pillar of the current environmental and alternative energy sector, and it has even come to lead this sector. Issues related to the alternative energy development in transportation sector have been integrated into the much wider scope of sustainable development [11, 13].

5   Smart Mobility Challenges

Nowadays, many mobility initiatives influence how people move around their city and get their daily needs as transportation is one of the essential daily routines. As smart mobility grows daily, multiple organizations are starting to invest more. Transportation improvement has created an enthusiasm that can be applied to its width because the main beneficiaries are the consumers [5]. However, urban scholars and urban planners are working on expanding Smart Mobility to improve the goals of city policies, reduce traffic congestion, and encourage greater productivity. There are many ways to explore Smart mobility concepts where new projects could change the daily routine of people moving around the city [3]. Many challenges can occur in this process. Information security, payment security, data privacy, and heterogeneous networks are classical challenges common in any information system and will not disappear in urban mobility systems. In smart mobility's ecosystem, legal challenges involve different players co-ordinating together efficiently, e.g., financial companies, private transportation providers, city administration, and users. Another challenge smart mobility will deal with is the privacy of both the citizens and the companies [11].

On the other hand, social challenges are critical as smart mobility can create job loss for many. Similar to the logic that states that robots will replace human workers, the introduction of self-driving vehicles is causing truck and taxi drivers to worry as people will not require drivers anymore. Moreover, smart mobility needs smart people who can efficiently handle advanced complex technologies as not all users are equally comfortable using new mobility services [12].

6   Smart Mobility: The Case of Saudi Arabia

Each generation brings innovations that can lead to 'smarter' urban transportation results. These innovations could include direct technological improvements, such as the internal combustion engine (ICE), or they could integrate new approaches to manage the transportation sector, which opens the door to new business models in the world of transportation. Additionally, these advances could enhance mobility stakeholders beyond the traditional public transportation operators, private vehicle owners, and producers. Transport innovations encourage more active, public, and shared transportation, telecommuting, and better use of existing road capacity to address important concerns such as vehicular emissions, transportation cost, travel time, congestion, safety, accessibility, and social equity. Butler et al. developed sustainability evaluation criteria to measure smart mobility systems. Butler et al. identified five main types of smart mobility: Intelligent transport systems, Demand responsive transport, autonomous vehicles, shared mobility, and electric mobility [3].

Smart mobility has started in implementation phases in various cities worldwide such as Singapore, UAE, Netherlands, France, USA, and many more [11]. Singapore aims to become the world's first true Smart Nation by utilizing advanced technologies to the fullest while improving the quality of life, strengthening businesses, and building stronger and bigger opportunities. Singapore is creating smart neighborhoods, such as the Tengah neighborhood, built upon smart planning tools with advanced technologies with smart initiatives to be implemented across the city [13]. Some of these initiatives are presented in Table 1.

The initiatives for implementing the Smart Mobility concept ranged from applying the system in new planned cities to the integration of the system within existing cities. The Netherlands, as an existing classical city, aimed to become one of the leading smart cities worldwide. The Netherlands started implementing the smart mobility concept in 2013, which already led to empowering the developments within the city. The Nether- lands national government has promoted the Netherlands as a front-runner in smart mobility. Several governmental programs have been initiated to have more efficient and effective approaches to transport issues than traditional measures [15]. The Netherlands initiatives range from traffic information services to multi-modal travel planners and from communicating automated vehicles to car-sharing services [16]. The Amsterdam government initiated a project called *AmSmarterdam* to improve the city with advanced technologies such as smart traffic management

Table 1 Smart mobility initiatives [14]

Project description	Country
Intelligent junctions: Smoothing the traffic flows and reducing door-to-door travel times by interactive communication between cars, lorries, public transport vehicles, bicycles, and emergency services with traffic lights and other signals and sensors	The Netherlands
Joint deployment: Motorists receive detailed information on road works over a secure WiFi connection. Cars serve as mobile traffic information sources and pass these data onto traffic control centers. Autonomous vehicles on public roads, following a fixed route, the so-called, WEpods (without a steering wheel or pedals)	The Netherlands
Travel between Ede-Wageningen railway station and the campus	The Netherlands
FREILOT project: Communication between the traffic lights at the busy arterial road and the lorries enabled the system to provide the drivers with speed advice, displaying the remaining time to green	The Netherlands
Connected Traffic Management Center (TMC) and Connected Fleets; Travel Time Reliability as a City Service for Connected Freight; and Safer Pedestrian Crossings for Connected Citizens	Denver, USA
"Smart Spine" corridors in Pittsburgh to improve the connections between isolated neighborhoods and major employment, education, and healthcare centers	Pittsburg, USA

to have a smarter flow, which manages and monitors sensors across Amsterdam to report traffic flow and parking availability. Amsterdam started with a pilot project for the smart parking platform that reduced the average required time to find a parking spot by 43% while reducing the parking cost to help drivers make smarter choices by revealing the cheapest options within a given area [15].

Another example of cities starting to implement smart mobility projects in Croatian cities as the country started different shared mobility projects such as public bike sharing, various ride-sharing apps, and apps for optimizing the usage of on-street and car parks by having smart parking and smart card in public transport [11]. Also, in the US, Denver created different initiatives such as the Connect Traffic Management Center (TMC) and Connected Fleets; Travel Time Reliability as a City Service for Connected Freight; and Safer Pedestrian Crossings for Connected Citizens. Another project in the U.S. called "Smart Spine" corridors in Pittsburgh improved the connections between isolated neighborhoods and major employment, education, and healthcare centers [6].

The smart city concept and smart city six dimensions are deeply rooted in the Saudi 2030 vision as it is clear that Saudi Arabia strives to transform its cities into smart ones, such as Riyadh, Dammam, and Jeddah cities or build new smart cities from scratch such as Neom, that includes the line city, and Oxagon. Saudi Arabia has a clear vision and commitment, and it prepared the required resources to achieve the 2030 vision [17].

For Neom as an example of smart city application Saudi Arabia; they are planning on building the first smart futuristic megacity in Neom development; that introduces a
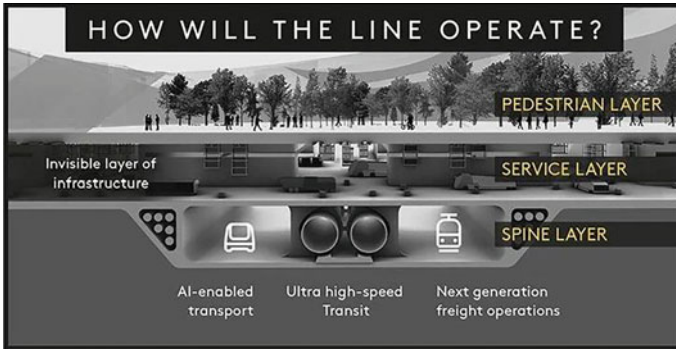
Fig. 2 The line city smart mobility layers. *Source* Neom Official Website, 2022 [18]

new model of urbanization and sustainability. The city is under construction and will be completed by 2030 [17]. Neom aims to provide a unique lifestyle to its residents by giving future technology in transportation, growing and processing food, healthcare, the Internet of things, and digital air as they build a city called The Line built on smart mobility (see Fig. 2). The line city is a 170-km linear city that creates a belt of communities connected without cars or roads, making the city completely free of cars while giving the residents direct access to nature and providing all of their daily needs within walking distance of five minutes [18].

Another example of smart mobility in Saudi Arabia started with SAPTCO governmental company as it started a smart mobility initiative called "Rekab," Which focuses on shared mobility at affordable prices through the use of smartphone applications. The initiative started in late 2021 in limited spaces in the main cities of Saudi Arabia" Riyadh, Jeddah, and Dammam. Saudi Arabia is gradually moving toward smart mobility; for example, Madinah established the first electrical charging unit to charge electric vehicles in March 2022. The main lesson learned of each case study are mentioned in Table 1 which shows a summary of a few examples of smart mobility initiatives [17].

7 Conclusion

Smart cities can be implemented by building a smart city from scratch using smart technologies and smart planning, such as the Tengah neighborhood in Singapore or the Line City in Saudi Arabia, which is built mainly on smart mobility. Alternatively, smart cities can also be implemented by transforming the current cities into smarter cities by plugging-in smart initiatives such as smart traffic systems, parking systems, electric vehicles, and smart shared mobility systems.

The concepts of smart mobility provide a broader horizon for implementing the concept of smart cities, intuitively with the creation of new cities, and in a more

effective and flexible way to develop and modernize existing cities and increase their efficiency to cope with the era of digital transformation.

Urban Mobility in the cities has become one of the biggest problems for local municipalities as they started to create sustainable and environmentally acceptable solutions for urban mobility because of the increasing number of private cars, road accidents, congested roads in the traffic network, less public space for people, and economic stagnation. Smart Mobility deals with various past and real-time data; with the help of various advanced technology solutions in each field of transport and traffic science, the possibilities for implementing technology into the transport sector are increasing.

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